

## **BACK GROUND OF INVENTION**

The present invention relates to a Peak Reduction Equalizer circuit to boost the output power of a multi-carrier wireless RF amplifier. The Peak Reduction Equalizer circuit input could be baseband, intermediate frequency (IF), or RF signal. and its output is the peak reduced RF signal as a new input to the amplifier. In any wireless communication system one of the critical components is the power amplifier. This component has a major contribution in cost, power consumption, and size of the system. The main reason is the requirement of wireless radio communication system for linear amplifiers. The higher the linearity, the higher the power consumption, cost and size. In order to minimize the cost, size and power consumption there is a need for techniques that overcome this problem. This invention conquers these challenges by using a simple and accurate Peak Reduction Equalizer module used at the input to the amplifier.

## **SUMMARY OF INVENTION**

According to the invention, a low-cost RF Peak Reduction Equalizer circuit, for use with multi-carrier RF amplifier, uses a plurality of simple and accurate circuits in conjunction with intelligent signal processing to improve power handling of the multi-carrier RF amplifier. By intelligent, it is meant that the Peak Reduction Equalizer module has features of restoring the signal emission and quality requirements after applying the Peak Reduction Equalizer function. The Peak Reduction Equalizer module uses the amplifier input which could be a baseband, an IF or RF signal as its input and conditions the input before applying to the multi-carrier amplifier. The conditioning or Peak Reduction Equalizer helps to boost the power handling of the amplifier or acts more linearly. The inputs to the Peak Reduction Equalizer should be within a limit that can be handled by the Peak Reduction Equalizer module.

In a particular embodiment, the Peak Reduction Equalizer unit comprises a multi-carrier transmitter and a multi-carrier broadband receiver, a signal processing, and a clock

generator. The receiver and transmitter convert the baseband, IF, or RF signal to digital baseband and the digital baseband signal to RF. The signal processor performs the signal conditioning as well as performs the initial calibration, and transmitter and receiver control.

The invention will be better understood by reference to the following detailed description in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an overall block diagram of the a amplifier with a booster using Peak Reduction Equalizer

FIG. 2 is the block diagram of the Peak Reduction Equalizer module

FIG. 3 is the block diagram of the digital processing unit of Peak Reduction Equalizer module

FIG. 4 is the block diagram of the digital signal processing block performing the Peak Reduction Equalizer

FIG. 5 is the detail block diagram of Peak Reduction Equalizer

## DESCRIPTION OF THE SPECIFIC EMBODIMENTS

In a first preferred embodiment the Peak Reduction Equalizer circuit monitors the signal strength of the multi-carrier input signal channels using the input receiver and finds the frequency and channel number of the input signals. In a second preferred embodiment of the invention, the Peak Reduction Equalizer circuit uses sub-harmonic sampling to convert multi-carrier RF or IF signals to digital baseband signal. In a third preferred embodiment the input signal is conditioned or peak amplitude reduced using the multi-carrier baseband signal. In a fourth embodiment the digital baseband signal is further down converted to produce the individual carrier baseband signal. In a fifth embodiment the multi-carrier signal is amplitude clipped or limited either in analog or digital domain. In a sixth embodiment the individual baseband signals are individually filtered, equalized and up converted to reconstruct the multi-carrier digital baseband signal.

Referring to Figure 1, a Peak Reduction Equalizer circuit diagram is illustrated. The systems receive its inputs from wireless transmitter 100. The output of the Peak Reduction Equalizer circuit 200 is applied to the input of the amplifier. The Peak Reduction Equalizer circuit performs the following functions:

1. Finds the frequencies and channel numbers of the multi-carrier wireless transmitter output 100.
2. Reduce the amplitude peak of the input signal 100 before applying to amplifier.
3. Adaptively adjust the gain in the signal paths to keep the total gain from input to output of the Peak Reduction Equalizer zero.

Figure 2 illustrates the detail block diagram of the Peak Reduction Equalizer circuit unit. The received signal from multi-carrier wireless transmitter 100 is applied to multi-carrier receiver 201 to produce signal 400. The output of the multi-carrier receiver 201 is applied to signal processing block 202 for digital signal processing which is Peak Reduction Equalizer and filtering / equalization of baseband representation of each carrier. The

output of signal processing block 202 the amplitude peak reduced signal 401 is applied to multi-carrier transmitter 203 to create the input signal 101 for the multi-carrier amplifier. Clock generator 205 produces all the clocks necessary for the Peak Reduction Equalizer circuit and the power supply block 204 produce all the voltages necessary for the Peak Reduction Equalizer circuit.

Figure 3 shows the detail block diagram of the Peak Reduction Equalizer signal processing block 202. The receiver block 201 output 400 is applied to analog to digital converter ( in case the signal is RF, IF, or baseband ) block 500 to produce the digital signal 410. If the signal is RF or IF the analog to digital conversion is based on sub-harmonic sampling. The output of the analog to digital converter 500 is applied to the DSP block 501 for down conversion and decimation to produce "m" sample per symbol. In case the signal is a multi-carrier baseband the signal may need to be interpolated or decimated to produce the right number of samples per symbol. If the signal is baseband but in bit format the up conversion function of 501 is used. The signal is converted to symbol domain with desired samples per symbol first and then each channel is up converted to its baseband frequency to produce multi-carrier baseband. The DSP block 501 also performs the Peak Reduction Equalizer and produce signal 411. The amplitude peak reduced signal 411 is applied to up converter and interpolator 503 to produce the up converted and interpolated signal 412. Signal 412 is applied to digital to analog converter 503 to produce the analog signal 401 for the multi-carrier transmitter block 203.

Figure 4 shows the block diagram of the Peak Reduction Equalizer block 502. The multi-carrier baseband signal 410 from the main multi-carrier receiver has its amplitude limited by amplitude limiting block 510 to produced amplitude limited multi-carrier signal 420. The amplitude limited signal 420 is down converted to single carrier baseband signals by block 511 to produce the baseband representative of each individual carrier. The individual single carrier baseband signals 421 are filtered by low pass filter and equalizer (LPEQ) block 512 to produce the filtered / equalized signals 422. The filtered / equalized signals 422 are applied to block 513 to reconstruct the multi-carrier baseband signal 411.

Figure 5 shows the detail block diagram of the Peak Reduction Equalizer circuit. The multi-carrier baseband signal 410 from the receiver is applied to amplitude limiting block 510 to produce amplitude limited multi-carrier signal 420. The amplitude limited signal 420 is applied to down converters 601, 602, and 603 to produce the baseband signal of each carrier 701, 711, and 721. The second input to down converters 601, 602, and 603 are supplied by NCOs 661, 662, and 663. The baseband representative of each carrier then is applied to Low Pass Filters / Equalizers (LPEQ) 611, 612, and 613 to maintain the emission properties of the signal. The filtered / equalized baseband representative of each carrier 702, 712, and 722 are applied to up converter blocks 651, 652, and 653. The other signal used by up converter is supplied by NCOs 681, 682, and 683. The up converted signals 706, 716, and 726 are then combined in block 600 to produced the new multi-carrier baseband signal 411. In figure 5 only a multi-carrier with 3 carrier is shown. This approach can be applied to unlimited number of carriers.